

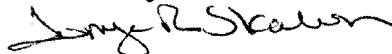
**The Correlation of Heart Rate and the Rate of
Perceived Exertion**

Senior Honors Thesis (HONRS 499)

by

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A handwritten signature in black ink, appearing to read "Tonya Skalon", written in a cursive style.

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Abstract

The purpose of this study was to investigate the correlation between Borg's Rate of Perceived Exertion (RPE) Scale (Appendix; 6) and heart rate responses produced with the Queens College Step Test (1). Resources required to perform this test included a stopwatch, a metronome, a 16.25 inch step, and an assistant. To conduct the test the subject steps up and down in cadence with the metronome for 3 minutes with the males stepping at a rate of 24 steps/min and females at a rate of 22 steps/min. At each minute the subject is asked to use the RPE scale, from 6 to 20, to describe how hard they feel they are working at that time. Within 5 seconds after the conclusion of the test, the subject's heart rate was recorded for 15 seconds and multiplied by 4 to find their heart rate. The results were then statistically compared to depict what kind of correlation existed between these two sets of data. The mean RPE and HR for the first minute of the test were 9.88 ± 2.04 and 141.69 ± 20.16 respectively. The second minute was 11.66 ± 2.16 and 153.78 ± 16.78 , and the third minute was 12.97 ± 2.10 and 158.47 ± 18.01 . The correlation coefficient was very small. R^2 for the first minute was 0.2096, the second minute was 0.1253, and the third minute was 0.1194.

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Chapter 1

Problem

In the Exercise Science field, we do $\text{VO}_{2\text{max}}$ tests (2) which measure cardiovascular endurance. One in particular is the Queens College Step Test (1). This test is done in our laboratories here at Ball State. During these tests, to assess and regulate exercise intensity, the subject is shown an RPE scale (Appendix), which is numbered from 6 to 20, and asked to assess their level of exertion at that time using this scale. In theory, the RPE scale is directly correlated with the subject's heart rate (HR) (6). I wanted to test this theory and determine if the RPE scale we use does accurately assess the subject's work rate.

Perceived exertion is how hard you interpret that your body is working. This feeling is based on the physical sensations experienced during physical activity, to include increased heart rate, respiration, or breathing rate, increased sweating, and muscle fatigue. Due to the subjectivity of the measure, it is questionable as to how accurate it can be to assess how hard the body is actually working. If your body is experienced at assessing how hard it is working, you can use that to increase or decrease current activity. Perceived exertion should reflect how heavy and strenuous exercise feels as a combination of all feelings and physical stress, not just one component such as muscle fatigue. Although the RPE scale can be used to assess one physical aspect of the body, it is more likely to be used to assess the body as a whole. The scale ranges from 6 to 20, where 6 stands for "no exertion at all" and 20 represents "maximal exertion." Think of 19 on this scale as extremely strenuous, for many people, this will be the most strenuous exercise they have ever performed. One has to be sure they are assessing their own

exertion and not comparing it to that of others. This can sometimes be difficult in a group setting where the subject can possibly be influenced by their surroundings (9).

With the obesity rate in the United States on the rise, fitness has become more and more popular, especially cardiovascular fitness. A VO_{2max} test can be used to assess a subject's current cardiovascular fitness and then to assess it later on in the program to evaluate progress. Borg's RPE scale can also be used in a home program, without a clinician present. A person can compare how hard they are working from the scale and how hard they need to be working for their program. A subject can also utilize their heart rate to assess how hard they are working, but if the RPE scale and heart rate are closely related, then one should be able to choose either method based on preference.

Purpose

This study was designed to demonstrate the correlation between Borg's Rate of Perceived Exertion Scale and heart rate. These trials were conducted in an EXSCI 201 class setting. RPE and heart rate were recorded after each minute of a 3 minute test. Subjects stepped up and down to the cadence of a metronome. The data was then collected and analyzed.

Delimitations

- 1.) Subjects were required to perform this test for their EXSCI 201 class, all of age 20 ± 2 yr.
- 2.) The Borg Scale of Perceived Exertion was utilized to subjectively evaluate the subject's work rate.
- 3.) The data collected applies to the Queens College Step Test.

4.) Each subject and assistant had instruction on how to administer and perform the test.

Limitations

1.) The subjects used were all members of the same class, so do not represent a random sample.

2.) The tests were not all administered by the same person, but each member of the class administered the test on their partner.

3.) The test administrators are at the beginning level of assessing heart rate.

Chapter II

Review of Literature

The Borg RPE scale was constructed by Gunnar Borg as a result of knowledge gained from psychophysical and psychological experiments. The original scale had 21 grades instead of today's 20, but there was something very interesting about this scale. On this original scale a grade of 17 was roughly similar to 170 beats per minute (bpm) in a group of normal healthy individuals. Although the bpm correlated with the RPE rating, there was a nonlinear relationship between ratings and workloads. Without a linear relationship, interpolations and extrapolations are relatively impossible. To increase the linear relationship, Borg moved the verbal anchors of the scale and decreased the rest value; the verbal anchors then corresponded to a linear growth function and were more easily interpreted. The first number of the RPE scale is 6 because a low resting heart rate for most adults is 60, and 60 divided by 10 is 6. Minor changes were later made to the verbal cues such as 6 being labeled with "no exertion at all" and 20 with "maximal exertion", "very very" was replaced with "extremely", and "fairly light" was changed to "light." 170 beats per minute (bpm) is the normal submaximal work rate for a normal healthy population, meaning that most healthy subjects would get to at least a rating of 17 during a test. A rating of 20 is an absolute maximum that most people have never before reached, for most tests 19 should be the highest intensity reached. This is the highest intensity that most people have ever achieved in running extremely hard for several minutes or carrying objects so heavy they can barely perform the task (6).

The actual running definition of perceived exertion is: the degree of heaviness and strain experienced in physical work as estimated according to a specific rating method

(6). Overall perceived exertion is composed of several different factors such as sensory cues, emotional factors, and rating behavior. Physical pain may have a large effect on the RPE that a subject reports during exercise. This will most likely be due to a person giving a more localized RPE such as muscle pain rather than an overall exertion to include cardiovascular and emotional aspects as well (12). It can be difficult to assess overall feeling if a considerable amount of muscular pain is felt; it can also be very hard to explain the process of evaluating the body as a whole.

The basic definition of reliability is the proportion of the total variance that is true variance (6). RPE was constructed to measure exercise intensity; therefore heart rate can be used as a parallel test for the testing of reliability. Borg (6) performed experiments to test this, and found very high correlations, for example correlations on the bicycle ergometer were 0.70 and 0.87 with increasing workloads. There is a drawback however, to parallel testing. Subjects know that the intensity is constant and that the perceived exertion should be about the same between different tests (6). Subjects may try and tell you what they think you want to hear.

The RPE scale has been tested and was successful for retest reliability. In a study by Borg and Ohlsson (7), subjects had to run 800m three times at three different speeds. During this time their HR and RPE were collected after each run. The correlation of HR between the first and second run was 0.74, between the first and third it was 0.64, second and third was 0.89. The correlations for RPE between the first and second was 0.75, the first and third 0.69 and the second and third 0.87. The subjects also ran two durations of 1200m in which the correlation of HR was 0.87 and the RPE was 0.91. These correlations demonstrated a very satisfactory retest reliability that was as accurate with

RPE as with HR. In a study by Komi and Karppi (6) a sample of 14 male and 22 female sets of twins were tested on the cycle ergometer with increasing intensity. The subjects were tested twice, with one week of rest between tests, performed after a maximum test. The sets of twins were tested simultaneously, but reported their RPE silently by marking a piece of paper so as not to influence each others response. The loads for the tests were chosen to correspond with 35%, 50%, 70%, 90%, and 100% of each person's maximal capacity. The retest correlation of the lightest work was low (0.37), but was high with the greater work loads, 70% being the highest (0.55-0.75.) It is easier to rate exertion when sensations are stronger and more noticeable, which would explain the reliability at these stages (8). These retest correlations are actually very high due to them being calculated for individual workloads instead of only 1 intensity. One could estimate that if considering all intensities, the correlation would be above 0.90 (6).

In one other experiment by Borg, Karlsson, and Ekelund (6), 20 male subjects were tested on a bicycle ergometer with two tests. For the first test the workloads were guided by HR alone, then for the second test RPE was used as the guide for differing workloads. Tests were performed with a week of rest in between. The workload that was rated 17 for both tests was used as the retest correlation. The correlation between the two was found to be 0.89 with is a very considerable correlation in that the tests used different protocols and there was a week of rest that separated the tests.

RPE has been shown to be useful for referencing high levels of exercise intensity in healthy males and females, and with practice, the scales ability improves at lower intensities (11). This may be due to the way the RPE scale is spread out. The lower numbers seem to have slightly smaller differences between each number than do the

higher numbers. At a lower work rate, it may be difficult to assess how hard one is working unless the scale is completely understood by the subject and even then, there may be a bit of confusion. One also may be looking to the future in the earlier stages of the test, preplanning an accurate progression through the scale. Fatigue could be a major factor in the way that a subject assesses their work rate. Not only could fatigue be a factor of how far one is from the beginning of the test, but also how far they are from the end. Fatigue increases with exercise, seen in both increasing RPE and also with diminishing performance. The concept of teleoanticipation is used to describe distance perception or consideration of the finishing point (5). When athletes were asked to maintain a constant RPE during exercise, work output decreased as time progressed, came to a plateau, and then increased at the end. From this, we can see that there is a regulation factor that starts from the end and works backward from that point. In Baden's study (5) expectation of the finishing point was also seen in a study of cycling where participants cycled for durations of 8 min and 16 min. The subjects heart rates were consistently higher during the 8 minute bout than during the first 8 minutes of the 16 minute bout. The pedaling cadences were consistent with both bouts, but were significantly higher during the last minute of each one. The lower HR seen in the longer duration could be attributable to attentional focus. Walster and Aronson (18) found that ratings of fatigue were higher in the 3rd trial of a 3-trial session than in the 3rd trial of a 5-trial session, proposing that feelings of fatigue are reserved for the last trial. Then in Rejeski and Ribisl (15) it was seen that RPE was higher in runners that ran for 20 minutes than when those same runners were told they were going to run for 30 minutes.

While exercising there seems to be two types of cognitive categories of thoughts in people. Association is one which includes bodily signals such as fatigue, pain, and runner's high, etc., the other is dissociation in which the person ignores bodily sensations and turns attention to daydreams, environment, etc. In more elite runners, Morgan and Pollack (14) found that associative strategies were more likely, and sub elite had a more dissociative strategy. This may be due to more elite being more in tune with their bodies and being trained to listen to what their body is feeling. It is possible that the same applies during exercise that applies to everyday conversations, attentional focus. Although many different conversations can be overheard, one may choose to block out all but one. Well, in exercise we are receiving many different stimuli at once, but we may only pay attention to those we choose to give our attention. St Clair Gibson, Lambert, and Noakes (17) suggest that if there is no set duration and subjects continue until overcome by fatigue, reasons for cessation of exercise may be due to mental fatigue such as concentration and motivation.

Baden, Warwick-Evans, and Lakomy (5) did a study on anticipated running distances. They did 2 studies, one in an outdoor setting with a running club consisting of two runs of 8 and 10 miles. The second study was in a clinical setting, on a treadmill and consisted of two runs; one of which the subjects anticipated 10 min and the on the other they anticipated 20 minutes but were stopped at 10. The first study demonstrated a positive correlation between RPE and associative thoughts that grew stronger over distance and was significant at the end of both the long and short runs. The subjects of this study were members of a running club that agreed to report their RPE and percentage of associative vs. dissociative thoughts throughout an 8 and 10 mile run. The results of

the study displayed that the RPE was higher all the way through the short run compared to the RPE of the long run. This supports the idea that duration affects RPE because the speed between the two runs was of minimal difference. The data support the explanation that there is a lower level of associative thoughts through the long run due to dissociative thoughts occupying the subject's attentional focus and leaving less room for physical sensation processing. In both runs the percentage of associative thoughts increasing initially, decreased in the middle and increased at the end of the run, but the percentage of associative thoughts was greater in the short run than in the long run. By looking at the cognitive strategy of a run, falling at the beginning, a plateau phase, and then increasing at the end, we can see that it may be possible that the psychological aspect of RPE can be similar to cognitive strategies. Study 2 also found a significantly higher RPE in the shorter duration than in the longer one. Study 2 did not find as large a similarity between cognitive strategies and attentional focus, but it did demonstrate that an increase in percentage of associative thoughts as the run increased and a larger increase at the end in the shorter duration as opposed to the longer. For both of these studies there were significant effects on RPE's with the different expected durations. For instance, subjects were more exerted at the 9 minute mark of the 10 minute run than during the 9 minute mark of the run in which they thought was to be 20 minutes in duration (5).

Baden, McLean, Tucker, Noakes, and St Clair Gibson (4) found in their study that RPE increased significantly in a test where subjects were told to run for 10 minutes then told to run for another 10 as compared to a test where the subjects were told to run for 20 minutes. The intensity of each run was the same therefore the changes in RPE were not physiological, but instead were psychological. This study suggests that the difference in

reporting's between the two tests were due to the feelings of affect which is a scale representing feelings of emotion instead of physical exertion. These feelings of affect decreased as the RPE increased in the 10 minute trial, but the RPE and affect were steady in the 20 minute trial. This study helps to demonstrate the psychological aspect of RPE, whether or not is related to affect is not my goal to figure out, but RPE in itself is affected (4).

When thinking about how subjects respond and why they respond that way, one has to think about factors in exercise that may affect what subjective feelings are reported. Some of those factors could include illness, hunger or satiety, previous exercise bouts, stress, and even anxiety. If a subject is under the influence of cold or flu-like symptoms, they are going to feel as if they are working much harder than what they normally would under the given circumstances. In a study by Backhouse, Bishop, Biddle, and Williams (3), the affect of carbohydrates (CHO) on perceived exertion was tested. The subjects were 9 endurance trained males, all of college age. The subjects fasted 10-12 hours before each test and abstained from any physical activity prior to test. Participants completed two exercise trials consisting of a 2 hour cycle ergometer ride starting at 70% of their VO_{2max} . Each subject was given a solution before, during, and after the test which consisted of either a CHO or placebo (PLA) solution. Both solutions were the same in appearance and taste, therefore none of the subjects knew which solution they were ingesting. The results of these tests concluded that HR and VO_{2max} were no different between trials, suggesting that the individuals were exercising at the same intensity for both trials. Their HR ranged from 158 to 170 bpm. The RPE in both trials were relatively similar, but there was a large spike in PLA and a drop in CHO at 75

minutes, that being the only large difference of RPE. CHO consumption increased feelings of pleasure during the prolonged cycling bout, therefore increasing the rating of RPE. The CHO trial did decrease in RPE at 75 min during the test. According to Coggan and Coyle (10), during exercise, reductions in RPE after CHO ingestion may be due to elevated circulating levels of blood glucose. Sparks, Cable, and Doran (16) demonstrated that environmental temperature increases HR and RPE during exercise. Temperature was shown to increase during running and stay steady during cycling. From this experiment we can see that temperature of the room during testing could in fact have an impact both on HR and RPE. If temperature stays relatively steady during cycling, the HR will possibly do the same, but if it is of an uncomfortably increased temperature in the room, the subject may report a higher RPE than normal.

Chapter III

Methodology

Subjects

The students in this study are Ball State students of the Exercise Science major, enrolled in EXSCI 201. These 32 students are males and females approximately 20 ± 2 years. All students enrolled in EXSCI 201 participated in the study required by their professors, as it is a lab requirement to do so.

Testing

I did not conduct the actual test per the Institutional Review Boards' suggestion, but the testing procedure took place in the Human Performance Laboratory on the Ball State University Campus. Resources required to perform the test included a stopwatch, a metronome, a 16.25 inch step, and an assistant. To conduct the test the subject has to step up and down in cadence with the metronome for 3 minutes with the males stepping at a rate of 24 steps/min and females at a rate of 22 steps/min. At each minute the assistant will ask the subject to use the RPE scale, from 6 to 20, to describe how hard they feel they are working at that time. Within 5 seconds after the conclusion of the test, the assistant took the subject's heart rate for 15 seconds and multiplied it by 4 to find the heart rate. The partners then switched and repeated the process. This data was collected from each student at the end of the lab and used for this research. The collection of data took no more than one lab period and lasted as long as it took for each student to get through the test.

Chapter 4

Results and Discussion

Due to its strong positive association with physiological variables (i.e. oxygen uptake and heart rate), the RPE scale is widely recognized as a means of estimating the intensity of an exercise bout (13). Evidence suggests that HR and RPE are positively correlated and can be used interchangeably to assess the physical exertion a subject is putting forth (6). Table 1 is a display of all individual subject data. Looking at the graphs (Fig 1-3) of the 3 minutes separately, one can see that the RPE increases steadily, but it is the HR's that are dispersed erratically. The correlation coefficients for all 3 phases of the test are very low; this is most likely due to the variation in HR. The graphs show a slight linear correlation, but not enough to be significant. Table 2 is a display of the AVG and SD of the HR and RPE collected for the 3 minute periods during the test. The mean of each RPE and HR may be a better demonstration of the results of this experiment due to the possible variation in HR and the inexperience of the examiners. Looking at the averages (AVG) of HR and RPE, they increase with each minute interval increase of the test. Standard deviation (SD) on the other hand, displays a minimal difference between each interval. Figure 4 is a graph of the mean obtained from each interval of the test, which presents a positive linear correlation and an r^2 value of .97 which is a very strong correlation as opposed to the low correlations obtained from each minute. The difference in correlations is obviously due to the variations in HR most likely due to the minimal practice and experience of the students in the class. Perhaps if it had been done in a graduate class or in a more experienced setting, the correlation from each minute would be very similar to that of the means. By taking the AVG of each HR

and RPE, one is able to remove the outliers that are resulting in an extremely low correlation and display a quite possibly more accurate correlation between HR and RPE.

It is often assumed that once a subject has been instructed on the usage of Borg's scale that they then have a complete understanding of that scale. This could be an issue with the validity of the RPE that a subject reports. On the other hand, the subject may in all actuality understand the scale and how to use it, but they may not understand how to read their body. A fitness conscious person is quite in tune with their body and which sensations they should and should not experience while exercising. They obtain the ability to decipher the difference between "muscle pain", "muscle soreness", and "muscle fatigue". They also know which feelings will be detrimental to their performance and at what stage they are when it comes to actual fatiguing of the body. A more sedentary individual may perceive a tight calf muscle as very painful and rate themselves at a 15 whereas a fit person with the same pain may rate themselves as a 12. An elite athlete in tune with their body and who has often undergone testing would theoretically be the best person to show a high positive correlation between HR and RPE. A person whom rarely exercises and has never before undergone exercise testing can likely have a high correlation, but it would be much less likely that their reported RPE is the true RPE.

It is likely that a subject is more likely to report a true RPE measure individually rather than in a group setting. When in a group setting, some individuals feel as though they must compete with the rest of the group; therefore, by reporting a lower RPE they will look as though they are in better health than their peers. This may not be true to all ages, genders, and populations, but in the younger population with competitive individuals (i.e. college students), it is apparent that sometimes the subject is searching

for the “right answer.” Also, with this being a classroom learning environment used for familiarization instead of a true test for the subjects estimated $\text{VO}_{2\text{max}}$, it is very likely that these tests were taken lightheartedly and possibly even hastily for the sake of getting it done and going home. Due to the circumstances of this test and the environment in which it was given, the mean values of HR and RPE are a more accurate means of assessing the correlation between these two values. This experiment then supports previous studies that in fact RPE could be used as a helpful means of obtaining the work rate of an individual during exercise testing and could in some cases be used in lieu of HR.

Tables

	RPE 1	HR 1	RPE 2	HR 2	RPE 3	HR 3
Subject 1	7	120	12	163	13	167
Subject 2	7	125	13	132	14	136
Subject 3	8	126	13	156	13	162
Subject 4	12	126	14	166	14	174
Subject 5	7	130	11	160	11	163
Subject 6	7	119	13	181	13	184
Subject 7	7	121	7	135	9	134
Subject 8	11	160	8	157	10	155
Subject 9	8	113	8	141	10	149
Subject 10	11	130	14	169	16	171
Subject 11	9	132	13	141	14	149
Subject 12	11	130	9	137	12	147
Subject 13	10	128	13	193	14	194
Subject 14	11	147	9	151	10	151
Subject 15	12	119	9	141	12	147
Subject 16	12	155	12	168	13	173
Subject 17	13	146	10	146	13	151
Subject 18	10	151	13	136	13	136
Subject 19	12	190	14	166	16	175
Subject 20	12	167	12	170	13	175
Subject 21	12	182	9	121	10	123
Subject 22	9	133	13	179	15	184
Subject 23	7	161	13	139	15	162
Subject 24	7	128	15	150	17	165
Subject 25	12	156	13	140	16	147
Subject 26	11	161	11	146	13	162
Subject 27	11	138	9	175	10	180
Subject 28	11	120	10	146	13	150
Subject 29	8	168	13	140	10	148
Subject 30	8	142	13	148	14	120
Subject 31	11	141	13	154	14	157
Subject 32	12	169	14	174	15	180

Table 1- Subject data collected from Queens College Step Test (1).

Table 2	<i>Averages and Standard Deviations of Heart Rate and RPE at each minute interval.</i>					
	RPE 1	HR 1	RPE 2	HR 2	RPE 3	HR 3
AVG	9.88	141.69	11.66	153.78	12.97	158.47
SD	2.04	20.16	2.16	16.78	2.10	18.01

Figures

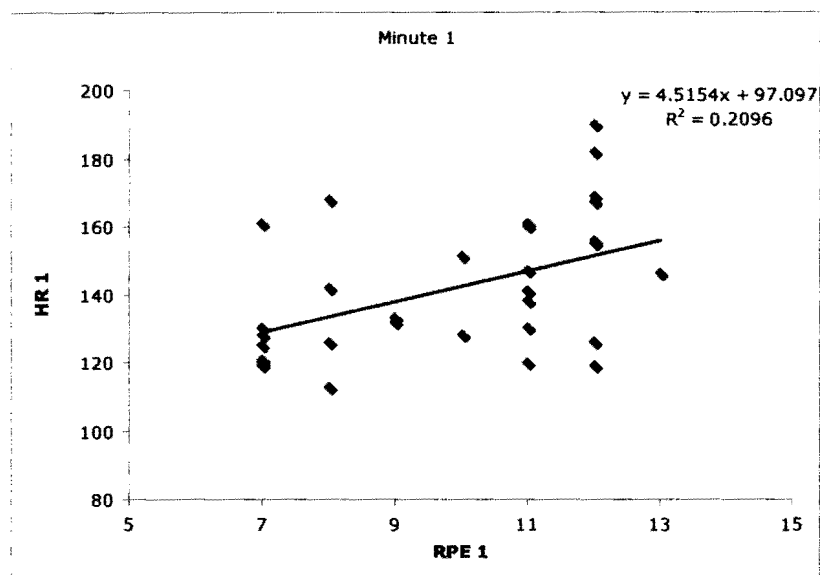


Figure 1- RPE and HR data collected from minute 1 of the Queens College Step Test (1).

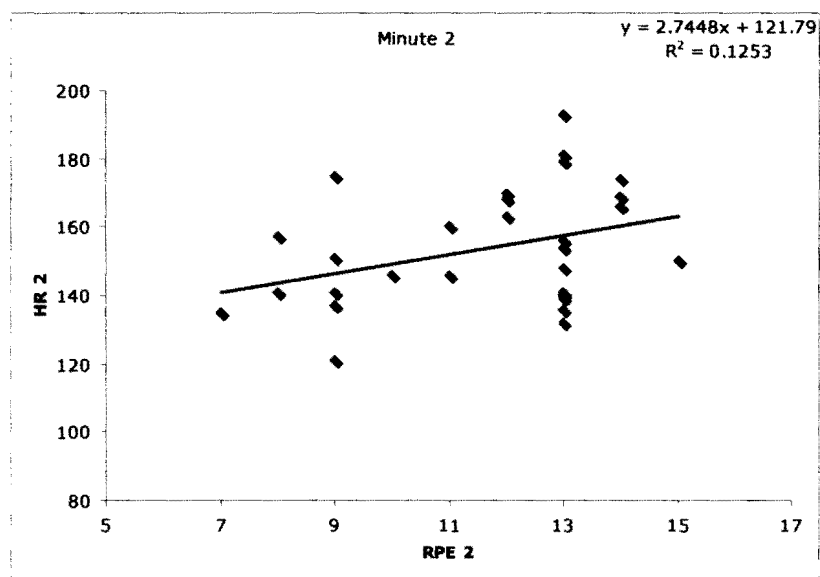


Figure 2- RPE and HR data collected from minute 2 of Queens College Step Test (1).

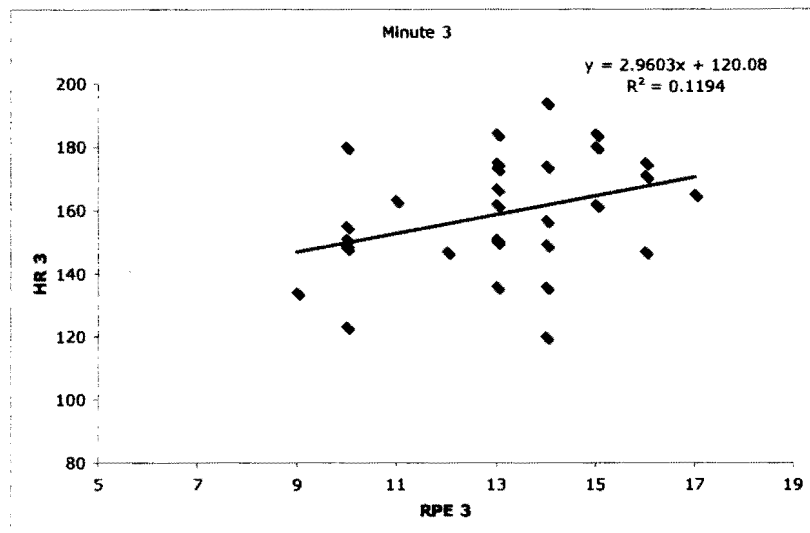


Figure 3- RPE and HR data collected from minute 3 of Queens College Step Test (1).

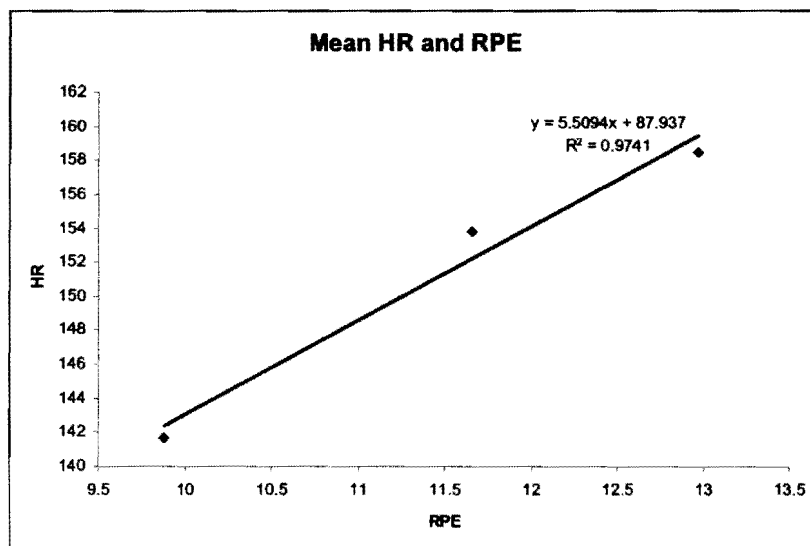


Figure 4- Mean HR and RPE data collected from Queens College Step Test (1).

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Appendix

Instructions for Borg Rating of Perceived Exertion (RPE) Scale

While doing physical activity, we want you to rate your perception of exertion. This feeling should reflect how heavy and strenuous the exercise feels to you, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any one factor such as leg pain or shortness of breath, but try to focus on your total feeling of exertion.

Look at the rating scale below while you are engaging in an activity; it ranges from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion." Choose the number from below that best describes your level of exertion. This will give you a good idea of the intensity level of your activity, and you can use this information to speed up or slow down your movements to reach your desired range.

Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Your own feeling of effort and exertion is important, not how it compares to other people's. Look at the scales and the expressions and then give a number.

6 No exertion at all

7

Extremely light (7.5)

8

9 Very light

10

11 Light

12

13 Somewhat hard

14

15 Hard (heavy)

16

17 Very hard

18

19 Extremely hard

20 Maximal exertion

9 corresponds to "very light" exercise. For a healthy person, it is like walking slowly at his or her own pace for some minutes

13 on the scale is "somewhat hard" exercise, but it still feels OK to continue.

17 "very hard" is very strenuous. A healthy person can still go on, but he or she really has to push him- or herself. It feels very heavy, and the person is very tired.

19 on the scale is an extremely strenuous exercise level. For most people this is the most strenuous exercise they have ever experienced.

Borg RPE scale

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